

Observations, &c. (*continued*).

- Verification of Standard Weights for Use in India. Folio.
London 1893. The Department.
 New Haven:—Astronomical Observatory of Yale University.
 Transactions. Vol. I. Parts 3—4. 4to. *New Haven* 1893.
 The Observatory.
 Vienna:—v. Kuffner'sche Sternwarte. Publicationen. Bd. I.
 4to. *Wien* 1889. The Observatory.
 Washington:—U.S. Department of Agriculture. Weather Bureau.
 Report of the Ohio Weather and Crop Service. December,
 1892. 8vo. *Norwalk* 1893; Maryland State Weather Service.
 Monthly Report of Observations. Vol. II. No. 9. 8vo.
 [1893.] The Bureau.
 Wellington, N.Z.:—Registrar-General's Office. Statistics of the
 Colony. 1891. Folio. *Wellington* 1892; Results of a Census
 of the Colony. 1891. Folio. *Wellington* 1892.
 The Registrar-General.

“On a Meteoric Stone found at Makariwa, near Invercargill, New Zealand.” By Professor G. H. F. ULRICH, F.G.S., of the University, Dunedin, New Zealand. Communicated by Professor J. W. JUDD, F.R.S. Received December 14, 1892,—Read February 2, 1893.

Introductory.

The stone under notice was not seen to fall, but the following description regarding the site of its discovery, its mineral character, and structure can leave no doubt of its being of meteoric origin.

Towards the end of the year 1886, when a large party of mining prospectors were preparing, with Government aid, for departure to the Big Bay district, west coast of Middle Island, Mr. Th. Fenton, a student of the Dunedin University School of Mines, was sent to Invercargill, where the party assembled, to instruct those of the men who desired it in rough assaying for gold and the use of the blowpipe. On the occasion of one of his lectures, he received from a Mr. Arch. Marshall, for examination, a piece of stone which, from its weight and appearance, was supposed to be something out of the common. Mr. Fenton made a rough qualitative analysis of a sample of the stone, and on finding strong reactions for nickel, thought it of sufficient interest to preserve the several small fragments remaining of the piece received from Marshall and to bring them with him to Dunedin, where he placed them at my free disposal. One of these fragments I devoted to the preparation of a number of thin sections

sliced in different ways, and the microscopic examination of these convinced me at once of the meteoric character of the stone. After this, I made every endeavour, by correspondence and ultimately travelling to Invercargill, to ascertain the exact locality where and under what circumstances the stone was found, and to obtain more of it if possible; for the surface outlines of the remaining fragments clearly indicated that it must originally have been of considerable size. The results of my investigations in these directions are the following:—In the year 1879, at the completion of the connexion of the railway line Invercargill—Winton and the branch line Makariwa—Riverton, two workmen, the brothers Arch. and I. Marshall, while engaged in removing a clay bank at Makariwa Junction, found in the clay, about $2\frac{1}{2}$ feet from the surface, a roundish stone, which at once attracted their attention, on account of its weight and because of the fact that in the clay-covered plain surrounding Makariwa Junction stones of any kind are a great rarity. They broke the stone with the pick and, finding the inside of different aspect from the outside, took the fragments home, and, experimenting with them, discovered that they affected the magnetic needle. With the intention of having the stone some day further examined, the pieces were kept as curiosities; but, being unsightly, they were kicked from one corner of the room into the other, and specimens were also occasionally knocked off for friends interested in the find. Mr. Arch. Marshall, who gave me these particulars, told me, on further inquiry, that the stone, when originally found, had a knobby, roundish shape, was of the size of a large man's fist, or perhaps a little larger, and might have weighed between 4 and 5 lbs. The exact place of the find was about half way between the railway station on the Winton line and the station master's house, some 20 feet from the line of rails. A search by Mr. Marshall for another piece of the stone which he thought was still somewhere about the premises at the time he gave the one to Mr. Fenton proved, unfortunately, unsuccessful, and the only secured remnants of this meteorite are the two pieces sent with this paper and another small piece divided between the Dunedin and Wellington Museums.

Macroscopic Character of the Stone.

All the fragments show portions of a yellowish-brown, rather soft, and earthy decomposition-crust, from 2 to 3 mm. in thickness, which evidently enveloped the entire stone when found. The undecomposed rock beneath this crust is very finely granular, rather hard and firm, and in fresh fracture dark greenish-grey, finely-mottled, light brown, and most nearly resembles fine-grained picrite in appearance; it slightly darkens, however, on exposure to the air, and shows on old fracture planes a dark brown, ferruginous glaze. Even under a strong

magnifying glass the nature of the minerals composing the rocky part of the stone cannot be determined, but tin-white metallic particles, abundantly present, can easily be distinguished; one also sees small, irregularly shaped pores or cavities, some partially filled with a brown ferruginous substance. After the fragments had lain untouched for some time in a closed box, there were also observed under the magnifying glass, on parts of the fresher-looking surfaces, very small drops of a dark brown fluid, which, however, spread and dried up before a micro-chemical test could be made. This fluid seems to originate the ferruginous glaze before mentioned, and may possibly consist of chloride of iron.

Microscopic Character of the Stone.

For the purpose of microscopic examination, seven thin sections were available, which proved the stone to belong to the "chondrites," or, according to Wadsworth, to the variety "saxonite" of the peridotites, and to be composed of the following minerals:—Olivine, enstatite, glass, a substance resembling glass, nickel-iron, troilite, and black opaque grains, probably magnetite. All the sections are, besides, more or less strongly flecked and stained with brown hydrous ferric oxide, originated, no doubt, through oxidation of the iron minerals.

Olivine.—This is the predominant mineral, and has a faint greenish-yellow colour in common transmitted light, but shows brilliant polarisation-colours between crossed nicols. It appears partly in well-defined chondrules, partly in larger and smaller grains of crystal-like or irregular outlines, closely packed together—the larger ones in some cases much, in others little, fractured; also in columnar bodies, some short and stout, others long and narrow, and sometimes curved, and all generally much fractured transversely—most fractures running at right angles to the length of the crystals, others obliquely, and from both sides. The extinction between crossed nicols of these columnar bodies is mostly parallel to their longitudinal extent, in cases more or less oblique, and it is rarely quite complete throughout, as small brightly coloured specks are generally observable here and there within the darkened body. The chondrules show various modes of internal structure. One kind is very fine granular, of dull-greyish or dusty aspect, and extinguishes pretty uniformly throughout, only some promiscuously distributed bright grains shining out. Around these chondrules large clear olivine grains, sometimes all of uniform, sometimes each of independent, optical orientation, are frequently arranged ring-like, and so that the divisional joints stand rudely radial (see figs. 3 and 6). This radial arrangement of the joints respecting grains is also observable, however, around groups of several larger grains as centre. A rare and pretty variety of the

kind of chondrule under notice is shown in fig. 1 (only one example was found in the several sections). In this the mass of the chondrule is constituted partly of fine granular dusky olivine, partly of an assemblage of large clear grains of this mineral, and has a ring of small clear grains of the same surrounding the fine granular part, whilst there is a border of dark grains of iron minerals around the whole. In another kind of chondrule the mass is divided or fractured by strong dark cracks into rudely parallel, columnar, and much cross-fractured portions, which generally extinguish between crossed nicols parallel to their length. The divisional cracks are sometimes so close together as to impart to the whole a coarsely fibrous structure. Some large chondrules occur also, exhibiting several systems of parallel cracks which meet at various, generally obtuse, angles, and in others, again, the cracks are eccentrically radiating. All the sections show patches of roundish or quite irregular outlines, which have a striking porphyritic structure, arising from the prevalence of an extremely fine granular dusty base, through which are distributed comparatively large clear crystals and irregular grains of olivine, and also occasionally enstatite; the base is probably also composed of a mixture of granules of these two minerals. Serpentinisation of the olivine was not observable in any of the sections.

Enstatite.—Besides appearing in the porphyritic mode just mentioned, this mineral occurs also sparingly distributed amongst the larger olivine grains and more abundantly in well defined chondrules. In the first case, it forms either columnar bodies, sometimes broad, but mostly narrow, or irregularly outlined grains—in fact, its forms are very similar to those of the olivine; and, as its colour is also next to identical with that of the latter—if anything, that of enstatite being fainter—the two minerals can hardly be distinguished in common transmitted light. In polarised light, between crossed nicols and on rotation of the stage, the difference is, however, very marked in that the colours of the enstatite are of a low order—only various shades of yellow and grey—contrasting strongly with the brilliant red, blue, and green colours of the surrounding olivine. One has to guard, however, against mistakes in this respect, as olivine grains cut at, or nearly at, right angles to one of the optic axes—of which there are examples in every section—show similar colours on rotation of the stage. The employment of convergent polarised light solves this question at once, and, in most cases, strongly marked cleavage-cracks are seen in enstatite, parallel to which extinction takes place, whilst generally, also, a finely fibrous structure becomes apparent on slightly lowering the polariser with its top lens. The chondrules are of rather dusty aspect throughout, or in cases only around the circumference, and have mostly an eccentric or fan-like fibrous structure, as shown respectively in fig. 2, lower margin, and fig. 5, upper margin. On

rotation of the stage, the extinction is undulating, approximately parallel to the fibre-lines, but a multitude of minute granules and lath-shaped bodies always shine out brightly along the darkened fibres. As in the case of the olivine, none of the sections show alteration of the mineral to serpentine.

Glass and a substance resembling Glass.—These require to be described together, because of their mode of occurrence and their likeness in common transmitted light. They are both perfectly colourless, transparent, and occur pretty abundantly, though mostly in small particles, filling generally larger and smaller crevices between the grains of olivine or of olivine and enstatite; their limpidness, combined with absence of colour, rendering them easily distinguishable from these minerals. The difference between the two substances consists in the one—the glass—being perfectly isotropic, the other anisotropic. The large finely-dotted patch near the centre of fig. 5, and the similarly dotted belt, enclosing several clear spaces, which extends in fig. 6 from the lower edge through the centre towards the upper edge, consist largely of the real glass. They show between crossed nicols a dark background, as it were, speckled with innumerable bright granules, polarising in fine colours, therefore, no doubt, olivine; and though on rotation of the stage the dark ground brightens up granular-like in many places, still there are numerous spots which remain perfectly dark throughout a complete rotation. In fig. 4 a large rather ill-defined olivine chondrule is delineated, in which the clear (undotted) parts on the right and left of, and also within the main part of the olivine near the upper edge, consist all of the anisotropic glass-like substance. For whilst between crossed nicols each separate particle shows dark and light spots—the light ones extinguish and the dark ones brighten up on rotating the stage—the extinctions are not, however, sharply defined, as in the former case, but cloudy or undulating, and there is also no chromatic polarisation. All things considered, it is very probable that the anisotropic substance simply represents glass in various stages of devitrification.

Nickel-Iron.—This is indicated in the figures by the dotted and cross-shaded areas, and is easily recognisable in the sections in reflected light by its metallic silvery-white lustre. As seen by comparison of the figures, it occurs in relatively large proportion, but is rather unequally distributed through the stone. The particles are highly magnetic and vary from very minute specks to such as approach a grain in weight. One such, for instance, was found on grinding a sample of the stone for chemical analysis. Larger particles sometimes enclose small grains of olivine, as shown in fig. 2 near the left-hand edge, and there occur also portions in some of the sections in which the iron forms a kind of rude network the meshes of which are occupied by olivine.

Troilite.—Rather small, yellow, and bronze-coloured metallic specks observable in the sections in reflected light belong, no doubt, to this mineral, but they are very scarce, and the aggregate percentage indicated by them, as present in the stone, would be very small indeed. According to the quantity of sulphur obtained in a preliminary chemical examination by Mr. James Allen, a former student of the Royal College of Science, London, the stone should, however, contain an appreciable percentage of troilite; and it is, therefore, very probable that some of the black grains, without metallic lustre, observable in the sections, belong to it, being partly oxidised and coated over by hydrous ferric oxide. Dark dull spots on the surfaces of many particles of the nickel-iron, or closely joined therewith, are very likely also due to this process.

Magnetite.—The majority of the rather abundant dark grains, some of which show square, others hexagonal, outlines, belong doubtless to this mineral. The distribution of the grains is very irregular; in some parts they are abundant, in others rather scarce; their closest aggregation is generally in the borders they form around chondri of olivine. Chromite may also be present, but only in very small quantity, as the chemical examination of the stone afforded only a trace of chromium.

Specific Gravity.

The specific gravity of the stone, determined from several small fragments, varied between 3.31 and 3.54: the variation is, no doubt, due to the unequal distribution of the metallic particles.

Results of the Chemical Examination of the Stone.

A chemical examination has since been undertaken by Mr. L. Fletcher, of the Mineral Department, British Museum. The examination is not yet finished, but the results already obtained by him indicate that the percentage mineral composition is approximately expressed by the following numbers:—nickel-iron, 1; oxides of nickel and iron, 10; troilite, 6; enstatite, 39; olivine, 44. The details of the examination will be communicated later.

Description of the Figures.

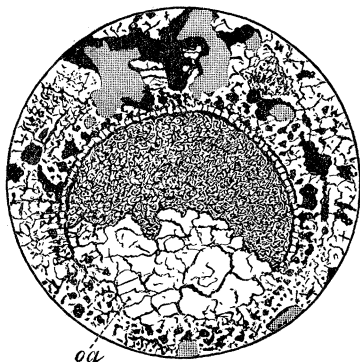
All the figures are drawn in ordinary light from thin slides cut in different directions from one of the fragments of the stone.* The nickel-iron particles, as seen in reflected light, are indicated by

* The small pieces remaining after the slicing were used for my preliminary chemical examination and the determination of the specific gravity.

dotting and cross-shading. Figs. 1—5 are magnified 25 diameters, fig. 6 is magnified 50 diameters.

Fig. 1.—This shows a nearly circular chondrule—the finest seen in any of the sections. It consists throughout of olivine: the upper very fine-granular part is somewhat dull or dusty, the lower coarse-granular part is clear, but some of the cracks are filled with dull-brown ferruginous matter. Around the circumference of the fine-granular part there is a rim of small clear grains of olivine, the divisional joints of which stand mostly radial; and around this rim again, also surrounding the coarse-granular part, there is a border of small, black grains of magnetite. The fine-granular part and its encircling rim of radial grains, as well as most of the grains of the coarse-granular part, have the same optical orientation,

FIG. 1.

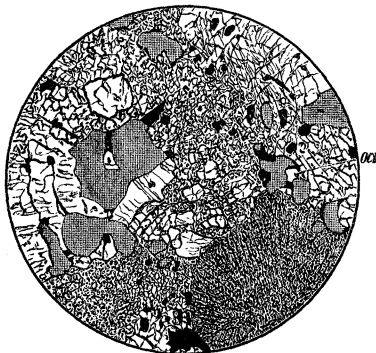


as they show pretty uniform simultaneous extinction between crossed nicols. In one of the grains of the coarse-granular part at the point indicated by a dotted line and the letters (oa) an optic axis is visible in convergent polarised light. What is seen outside the chondrule consists of an aggregate of larger and smaller grains, and several very fine granular patches of olivine showing aggregate polarisation and enclosing a number of particles of nickel-iron and dark grains, some of which, of dull-bronzy lustre, may be troilite. The two large particles of nickel-iron near the upper edge of the figure are so connected by and with a dull dark substance as to render it very probable that this substance is also nickel-iron, which, through oxidation, has lost its metallic lustre.

Fig. 2.—This shows on the lower margin, a little to the right, part of a large chondrule of enstatite rendered fibrous by fine eccentric striæ, and rather densely filled with fine dark dust. Between crossed nicols on rotation of the stage its polarisation colours are of a low

order, varying between light yellow and bluish-grey, and extinction takes place in an undulating manner, mostly parallel to the fibration. In reflected light it looks yellowish and opaque. The remainder of the section consists of olivine, in part finely granulated, in part in larger and smaller grains, sprinkled with particles of nickel-iron and dark grains of iron ore. At the left-hand margin, nearly enclosing two particles of nickel-iron, is a large grain of olivine which is divided

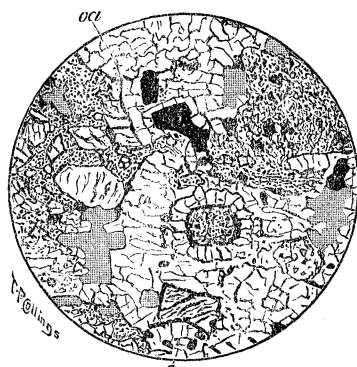
FIG. 2.



into columnar portions by rudely parallel fractures in the line of which extinction takes place between crossed nicols. In the finely granulated centre of the figure, scattered larger grains of olivine produce quite a porphyritic appearance which becomes more pronounced through the different optical orientation and the fine polarisation-colours of these larger grains. The largest particle of nickel-iron encloses a grain of olivine in the centre; and a deep indentation of another particle of the metal, seen close above the enstatite chondrule, is occupied by an olivine grain showing an optic axis (*oa*) in convergent polarised light. Some particles of the nickel-iron have narrow, dark margins, produced, no doubt, by oxidation.

Fig. 3.—Near the centre of the figure is represented a fine granular chondrule of olivine surrounded by a rim of clear grains of this mineral, the divisional joints of which stand generally radial. The optical orientation of this rim and that of the centre part are different, the latter uniformly extinguishing between crossed nicols when the rims of the grains are bright, while all the grains become dark simultaneously when the centre part is bright. Below this chondrule, near the lower right-hand margin, is a rather rudely-radial arrangement of olivine grains around a centre part consisting of four grains of this mineral, but in this case the centre grains extinguish simultaneously with the surrounding ones, thus proving the whole to be a large

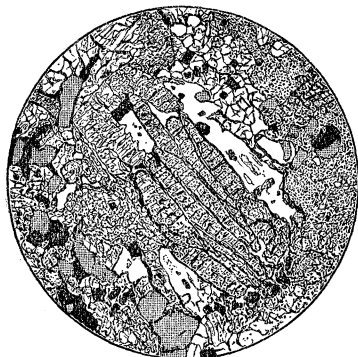
FIG. 3.



grain cracked in the manner shown. The oblong grain near the lower margin indicated by a dotted line and the letter *e* is enstatite. It shows strongly marked cleavage-cracks oblique to its outlines, polarises in low colours, ranging between light brown and grey, and extinguishes parallel to the cleavage-cracks. The remainder of the section is constituted of finely and coarsely granulated olivine, polarising aggregately, and enclosing a number of particles of nickel-iron and dark grains, the largest one of which, near the centre of the section, is probably oxidised nickel-iron, as it shows minute metallic spots in reflected light. A porphyritic structure, similar to that noticed in the previous section, is seen in the finely granulated olivine portion along the left-hand margin, the larger olivine grains, each of independent optical orientation, shining out brilliantly in polarised light from the duller fine-granular part. In a grain, indicated by (*oa*), near the upper margin, a fine optic axis is disclosed in convergent polarised light.

Fig. 4.—This shows a large chondrule, mainly composed of olivine, rather rudely defined by a border of particles of nickel-iron and dark grains, most of the former occurring around the left-hand margin. The portions of this chondrule left clear, *i.e.*, unshaded, consist of the water-clear, doubly refracting substance, resembling glass. A large amount of this occurs along the right-hand margin, smaller portions around the left-hand margin, and within the mass of the olivine, and it also fills the large rudely-parallel longitudinal fissures, and some large irregular transverse cracks by which the latter is divided. Whilst portions of it are perfectly clear between crossed nicols, others are dark; but on rotation of the stage the extinction travels in an undulating or cloudy manner over the light portions, and those dark before become light. The contrast between it and the olivine is especially well marked during the rotation, as the latter mineral, though much stained with hydrous ferric oxide, polarises in splendid

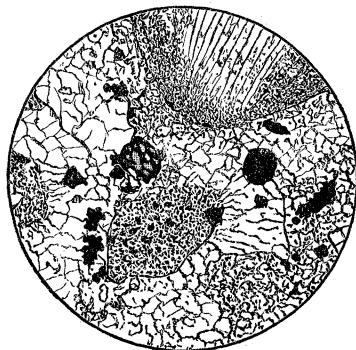
FIG. 4.



colours, and when its extinction takes place—which is in the line of the fissures dividing it into columnar bodies—the glassy substance in most of the fissures and cracks shows out perfectly clear and bright. The very finely granular part which bounds the chondrule on the right-hand margin and contains a number of larger grains, is also olivine, judging from the polarisation-colours. Some of the nickel-iron particles show dark spots and narrow dark rims, due to oxidation of the metal.

Fig. 5.—On the upper margin of this is shown part of a large chondrule of enstatite, which is finely fibrous, with the fibre-lines disposed in a fan-like manner. Around the margin it looks minutely granular and somewhat dusty; in the centre it is clear. Between crossed nicols it polarises in shades of yellow and grey, and extinguishes in the clear centre part parallel to the fibre-lines, whilst in the marginal dim part the extinction is cloudy. The large, finely-dotted patch near the centre of the section consists of a mixture of

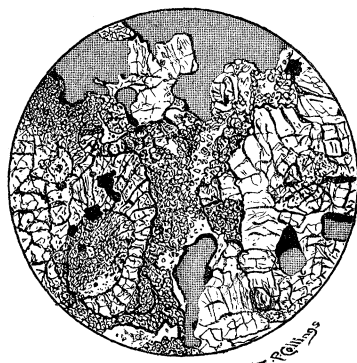
FIG. 5.



clear, isotropic glass and granularly devitrified anisotropic glass, and is full of minute, dark grains, probably of iron ore. The portion below the dotted part, near the edge of the figure, is mostly true glass and free from oxide of iron, but encloses a few small grains of olivine. The remainder of the section is occupied by finely and coarsely granulated olivine, strongly stained in places by brown hydrous ferric oxide, and there are also scattered dark grains—some rather large—in one of which, on the left of the centre of the figure, reflected light reveals numerous fine silvery-white metallic specks of nickel-iron. This is the only direct evidence of the presence of this metal in the section, but it is very probable that amongst the other large dark grains one or more consist of it to some extent, being rendered dull non-metallic-looking by oxidation.

Fig. 6.—This is drawn under twice the magnifying power used for the other figures, in order to show more clearly an occurrence of intermingled isotropic and devitrified anisotropic glass. The mass extends from the lower margin of the figure between a particle of nickel-iron on the right and an olivine chondrule on the left, upwards through the centre to the large particle of nickel-iron at the upper margin, being wider both at the top and bottom than in the centre. It is crowded with small, yet well-defined, grains of olivine, but

FIG. 6.



adjoining the lower particle of nickel-iron, and near the upper one, there are irregularly outlined portions quite free, or nearly free, from these grains, in which the true glass can plainly be distinguished from the granularly devitrified material between crossed nicols, on rotation of the stage of the microscope. Besides this mass of glassy substance, the particles of nickel-iron, and a few black grains, only olivine is represented in the section; the fine granular chondrule on the left having for the greater part a rim of larger grains, the divisional joints of which stand closely radial.

FIG. 1.



FIG. 2.

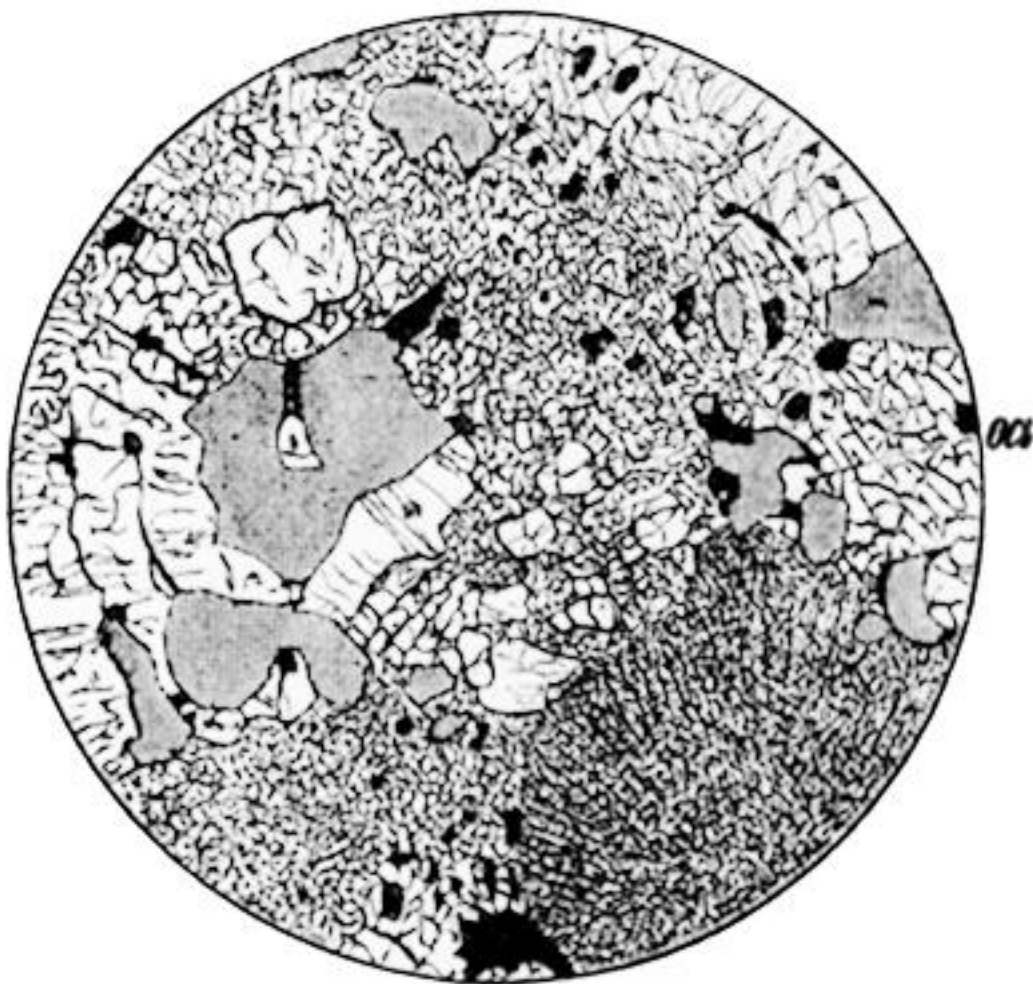


FIG. 3.



FIG. 4.



FIG. 5.

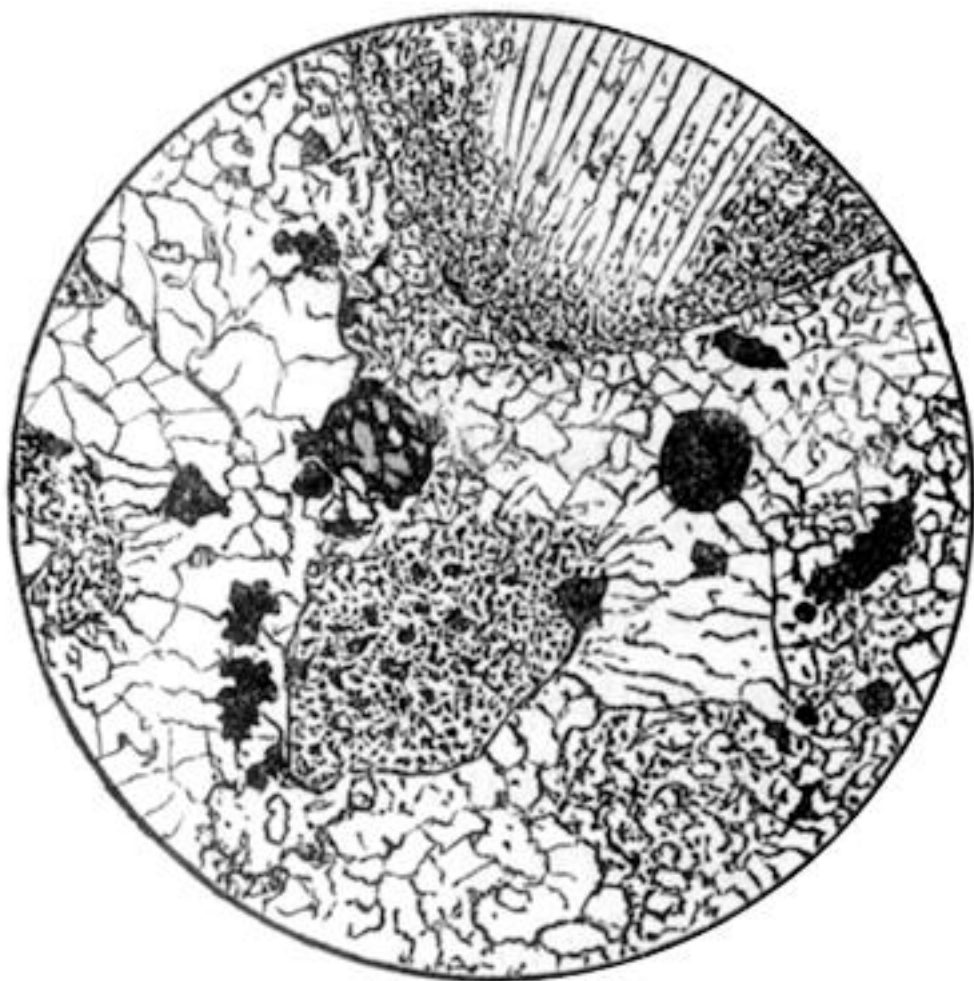


FIG. 6.

